Large Eddy Simulation of Three-Dimensional Bottom Density Currents

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ABSTRACT

We first describe the mathematical and numerical setting for our investigation of bottom density currents. We present 2D and 3D results for the Direct Numerical Simulation (DNS) of density currents. In Section 3, we describe the Large Eddy Simulation (LES) approach and its computational advantage over DNS. Section 4 presents some modifications needed in the LES of stratified flows. Finally, Section 5 describes the LES procedure for bottom density currents and the associated challenges.

1 Mathematical and Numerical Setting

- nonhydrostatic 3D numerical simulations
- Nek5000-parallel spectral element Navier-Stokes solver
- $\frac{dR}{dt} = \frac{1}{\rho u} \frac{\partial}{\partial x} \left( \rho u \right) = \frac{\partial}{\partial x} \left( \rho u \right) + \frac{\partial}{\partial y} \left( \rho u \right) + \frac{\partial}{\partial z} \left( \rho u \right)$
- $\frac{dS}{dt} = \frac{1}{\rho u} \frac{\partial}{\partial x} \left( \rho u \right) = \frac{\partial}{\partial x} \left( \rho u \right) + \frac{\partial}{\partial y} \left( \rho u \right) + \frac{\partial}{\partial z} \left( \rho u \right)$
- $\frac{dS}{dt} = \rho u (\partial S/\partial x)^2 + (\partial S/\partial y)^2 + (\partial S/\partial z)^2$

2 2D and 3D Direct Numerical Simulations

2D and 3D Salinity Distribution at t=9350

3 Large Eddy Simulation (LES)

- DNS computational cost = $(O(Rc)^3)$
- $\tau = \frac{\partial u}{\partial x}$
- Classee problem $\tau = \frac{\partial u}{\partial x}$
- eddy-viscosity LES models (Smagorinsky)

$$\tau = \left( C_D \beta^2 |\nabla u| \right) / |\nabla u|$$

where $C_D = \frac{\nabla u}{\nabla u}$ is the deformation tensor

- approximate-deconvolution LES models (Rational)

$$\tau = \left( C_D \beta^2 |\nabla u| \right) / |\nabla u|$$

4 LES for Stratified Flows

- stratification vs. buoyancy
- Richardson number

$$Ri = \frac{-Bc}{(\nabla u)^2 + (\nabla u)^2}$$

- Ri-dependent LES models

$$\tau = C(Ri, j) \left( \nabla u \beta^2 |\nabla u| \right)$$

where $C(Ri, j) = \sqrt{1 + \frac{Bc}{(\nabla u)^2}}$ if $j = 3$ and 1 otherwise

5 LES for Density Currents: Challenges

- eddy-viscosity or decovolution?
- Ri-dependence?
- boundary/initial conditions - filtered?
- variable or constant $Ra, Pr, \gamma_0$ etc.?
- what form for $t$?
- a posteriori tests - compare with the filtered fine DNS

References